DOCUMENT RESUME

ED 275 605 SO 017 661

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TITLE Utilizing Tornado Data for Classroom Exercises.
PUB DATE 10 Oct 86
NOTE 27p.; Paper presented at the Annual Meeting of the National Council for Geographic Education (Chicago, IL, October 10, 1986).
PUB TYPE Guides - Classroom Use - Guides (For Teachers) (052) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Data; *Data Interpretation; Geographic Regions; *Geography Instruction; Higher Education; *Learning Activities; Maps; Map Skills; Secondary Education; Units of Study; *Weather
IDENTIFIERS *Tornadoes

ABSTRACT

Exercises were developed using tornado statistics to provide students with a better understanding of the spatial and temporal characteristics of these phenomena in the United States. Four categories of exercises were considered beginning with the simplest and progressing to the more complex. The first set of exercises required students to interpret tornado data. The second set utilized maps and posed questions about the frequency of tornadoes and associated fatalities. The third set required students to graph data and interpret trend lines in order to understand relationships. The fourth set used the Spearman Rank Correlation to confirm suspected spatial relationships examined in earlier exercises. The sample questions developed for each of the exercises served as examples of what could be done with tornado statistics. It is hoped that the questions and data will encourage users to expand on existing exercises, as well as to develop new ones for the classroom. Six tables of tornado data and corresponding maps are included. (Author/APG)

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UTILIZING TORNADO DATA FOR CLASSROOM EXERCISES

Paper Presented

at

National Council for Geographic Education

Chicago

October 10, 1986

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UTILIZING TORNADO DATA FOR CLASSROOM EXERCISES

Exercises were developed using tornado statistics to provide a better understanding of the spatial and temporal characteristics of these phemomena in the United States. Four categories of exercises were considered beginning with the simplest and progressing to the more complicated. The questions developed for each of the exercises served as examples of what can be done with such data. Hopefully, they will encourage the user to expand on existing exercises, as well as develop new ones for the classroom. It is recommended that before attempting the exercises a student should read the section on tornadoes that appears in Ahrens for a concise but thorough discussion(see references). If that book is unavailable Navarro or Miller provide a satisfactory summary, although not as thorough.

The first set of exercises required students to interpret tornado data. The next group of exercises utilized maps and posed questions about the frequency of tornadoes and associated fatalities. A third type of exercise required students to graph data and interpret trend lines in order to understand relationships. The final group of exercises used Spearman rank correlation to confirm suspected spatial relationships examined in earlier exercises.

Table 1 contains information about tornado frequency and tornado deaths recorded on a yearly basis in the United States. A sample of the kind of questions that can be developed using this data follows along with some possible answers.

Question 1A: Calculate the average number of tornadoes occurring for the period prior to 1971 and since 1971. Round to the nearest whole number.

Answer: The average for the 11 years prior to 1971 was 680 per year. The average for the 15 years since 1971 was 872 per year.

Question 1B: Compare the figures in the answer to question 1A with the overall average of 791 for the 26 year period. What generalization can you make regarding past and future trends in tornado frequency?

Answer: Tornado activity has increased since 1971 on the average compared to the years prior to 1971.

Question 1C: Suggest several reasons for the noticeable increase in number of tornadoes since 1971.

Answer: Weather conditions may be more conducive to tornado development and/or reporting accuracy has increased compared to previous years.

Question 1D: Based on the data since 1971 what would be your forecast for tornado frequency during 1986?

Answer: Based on the average since 1971 you might forecast an above average number of tornadoes since during the period only four years have been below the average of 791 and there have never been two successive years of below average tornado activity. On the other hand, 1986 could be the exception to the pattern exhibited in the previous 15 years. Forecasting is a risky affair when weather related phenomena are concerned.

Question 1E: Note that since 1975 deaths from tornadoes decreased significantly compared to previous years, yet the number of tornadoes remained above average. How do you explain this indirect relationship?

Answer: There are several possibilities. Greater public awareness as a result of public education could prompt people to seek shelter more readily during tornado activity. Also, there may have been fewer strong tornadoes which usually are

TABLE 1

TORNADOES AND TORNADO DEATHS IN THE UNITED STATES 1960-1985

Year	Number of Tornadoes	Tornado Deaths
1960	616	47
1961	697	51
1962	657	28
1963	464	31
1964	704	73
1965	906	296
1966	585	98
1967	926	114
1968	660	131
1969	608	66
1970	653	72
1971	888	156
1972	741	27
1973	1102	87
1974	947	361
1975	920	60
1976	835	44
1977	852	43
1978	788	53
1979	826	83
1980	864	28
1981	774	24
1982	1027	64
1983	931	34
1984	908	122
1985	682	94
	Average=791	Average=88

responsible for a majority of deaths. Finally, densely populated areas could have been missed by tornadoes more frequently than in the past.

Question 1F: How accurately could you forecast the number of tornado deaths for 1986 using the data in Table 1?

Answer: Not very accurately. It is difficult to know whether the higher than average number of deaths since 1984 will continue especially since this pattern of above average deaths for two successive years has not been duplicated in the last 15 years.

Table 2 contains tornado data for the State of Illinois from 1960 to 1985. Some sample questions follow using this data along with some possible answers.

Question 2A: Compute the average number of tornadoes per year occurring in Illinois. Round to the nearest whole number.

Answer: The average is 27 tornadoes per year.

Question 2B: Compute the average number of tornado deaths per year in Illinois. Round to the nearest tenth.

Answer: The average is 4.5 deaths per year.

Question 2C: Why would it be misleading to use only the average value computed in question 2B in describing tornado deaths in Illinois?

Answer: It would be misleading because some years have no deaths registered while others were above average. It is best to use both the actual data and the average when making comparisons.

Question 2D: In 1974 Illinois experienced 107 tornadoes but only two deaths. In 1967 a total of 40 tornadoes were recorded along with a 26 year high of 59 deaths. What do these situations reveal about the relationship between number of tornadoes and tornado deaths in Illinois?

Answer: The relationship is not a direct one. An above average number of tornadoes do not necessarily produce an above average number of deaths.

Question 2E: What other characteristics of tornado activity might help explain the situation noted in question 2D?

TABLE 2

TORNADOES AND TORNADO DEATHS IN ILLINOIS 1960-1985

Year	Number of Tornadoes	Tornado Deaths
1960	40	0
1961	34	2
1962	13	0
1963	11	2
1964	7	0
1965	28	8
1966	11	1
1967	40	59
1968	8	8
1969	10	0
1970	17	0
1971	16	1
1972	30	5
1973	63	0
1974	107	2
1975	46	2
1976	27	4
1977	33	6
1978	13	1
1979	12	0
1980	14	0
1981	33	1
1982	35	13
1983	14	2
1984	34	1
1985	13	0
	Average=27	Average=4.5

Answer: The intensity of the tornado, length of time on the ground, proximity to populated areas, adequate warnings and time of day are all additional factors which should be considered when attempting to explain the pattern of tornado deaths.

Figure 1 provides information about tornado incidence in the United States on an average monthly basis. This is the most recent data available from the National Weather Service. A sample of some questions that could be asked follows along with some possible answers.

Question 3A: How would you characterize the relationship between the number of tornadoes occurring monthly and temperature? (direct, indirect or undetermined)

Answer: Direct, since tornadoes are most common when the temperature is higher.

Question 3B: Consider the weather conditions responsible for tornadoes generally and then offer a reason why tornado incidence decreases steadily after the month of May.

Answer: Cooler air has receded northward providing for less contrast in air masses that normally meet to produce the turbulent conditions necessary for tornado development in the spring and early summer.

Question 3C: Calculate the percentage of tornadoes, tornado deaths and tornado days occurring during the months of April, May and June.

Answer: Tornado frequency for these three months is 55%(406/736) of the yearly total. These three months also account for 74%(78/106) of all tornado deaths. Tornado days for these three months amount to 40%(68/171) of the yearly total.

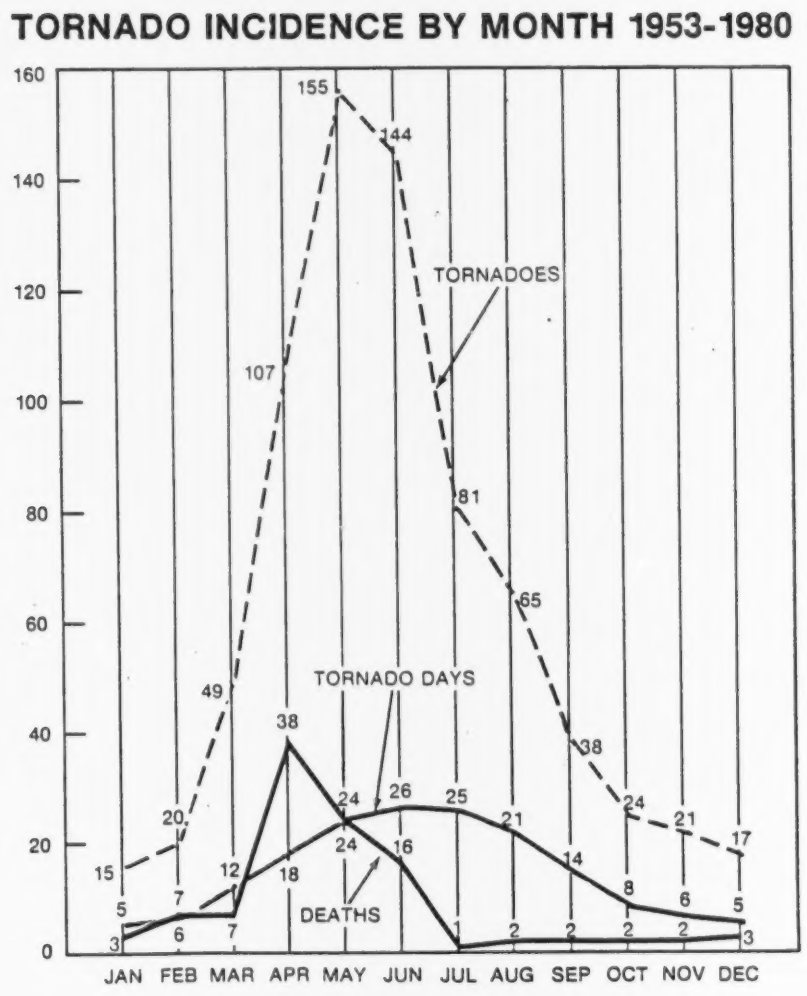
Question 3D: Speculate about why tornado deaths are highest during April on the average while the number of tornadoes is greatest during the month of May.

Answer: There are several possibilities. Once the tornado season begins people become more conscious of tornadoes and take greater precautions in May than in April. Tornadoes that develop in April, even though fewer in number, may be more intense which could account for more deaths.

Question 3E: Which one of the three curves in Figure 1 reveals the least variation from month to month?

Answer: Tornado days.

FIGURE 1


TORNADO INCIDENCE BY MONTH 1953-1980
160
140
120
100
80
60
40
20
0
TORNADOES
TORNADO DAYS
DEATHS
155
144
107
81
65
49
38
38
24
21
17
20
15
26
25
24
24
21
16
14
12
18
8
7
6
5
7
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5
3
2
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2
2
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1
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Question 3F: Calculate the number of tornadoes per tornado day for the months of January and May. Round to the nearest tenth.

Answer: For January the figure is 3.0(15/5). For May the figure is 6.5(155/24).

Question 3G: What does the answer in question 3F indicate about the relationship between tornado frequency and tornado days?

Answer: When tornadoes occur you can expect slightly more than twice as many on any tornado day in May as compared to January.

Question 3H: Examine the month of July and then describe briefly the relationship among the three tornado characteristics displayed in Figure 1.

Answer: Tornado incidence during July is higher than the monthly average of 61 with tornado days being the second highest of any month. Deaths from tornadoes are the lowest of any month. The number of tornadoes/tornado day(3.2) is slightly less than the average of 4.3.

The diurnal variation in tornado occurrence is presented in Table 3 for those states with the greatest tornado activity. Some sample questions follow using this data.

Question 4A: Why do you suppose that on the average the majority(55%) of tornadoes occur between 2 PM and 8 PM?

Answer: During the afternoon when air temperatures are highest the potential energy is greatest for lifting the air when atmospheric conditions are conducive to tornado formation.

Question 4B: Six states have values of less than 50 percent for the 2 PM to 8 PM time interval. Locate these states on Figure 2. What do they have in common that may account for this variation?

Answer: These southern states are warmer because of lower latitude and their positions adjacent to the Gulf of Mexico insure that moisture content will be high. This combination provides greater amounts of energy which can be more readily utilized, even during the evening, in the formation of tornadoes compared to states farther north.

Question 4C: Why would tornado spotting and the issuing of watches or warnings probably be less effective in alerting the public in Louisiana than in Nebraska?

TABLE 3

HOURS OF TORNADO OCCURRENCE

State	2PM-8PM(%)
Nebraska	76
Kansas	72
Wisconsin	68
Iowa	66
Minnesota	65
Illinois	63
Indiana	63
Missouri	57
Oklahoma	57
Arkansas	53
Texas	49
Florida	42
Alabama	38
Mississippi	37
Georgia	36
Louisiana	34
Average	55

FIGURE 2

MAP LOCATION FOR DATA FROM TABLE 3

Answer: Since tornadoes occur more frequently after 8 PM in Louisiana they would be hidden from spotters by darkness. It would also be more difficult to alert the public during the late evening or early morning hours when most people are sleeping.

Table 4 contains data about tornadoes for the 20 states where these violent storms occur most often. Note that tornadoes in Column A have been ranked from highest to lowest to assist in comparisons. Place the average number of tornadoes per year from Column A within the state borders on Figure 3. Some sample questions follow along with the answers.

Question 5A: In which region of the United States do tornadoes occur most often?(south, east, west, north or central)

Answer: The central portion of the United States.

Question 5B: Note the five states which are ranked highest in tornado activity in Column A. Can you offer a reason why Florida is not contiguous to the other four states?

Answer: The Florida peninsula extends southward into the warm ocean waters where hurricanes are encountered that frequently produce multiple tornadoes which accounts for the larger than expected number of these phenomena.

Question 5C: The State of Texas experiences more than twice as many tornadoes on the average as the State of Oklahoma. Texas is almost four times as large in area. Using these comparisons which state has the greater density of tornadoes for its area?

Answer: Oklahoma, because if its area was increased by a factor of 4, so it was equal in size to Texas, it would have proportionally about twice as many tornadoes compared to Texas.

Question 5D: In which direction does tornado activity decrease most rapidly from the State of Texas?(north, east or west)

Answer: Toward the north.

Question 5E: What two types of air masses most often interact to produce tornadoes in the central region of the United States?

Answer: Maritime tropical and continental polar air masses.

Question 5F: The east and west coasts of the United States experience considerably fewer tornadoes than the central part of the country. Why?

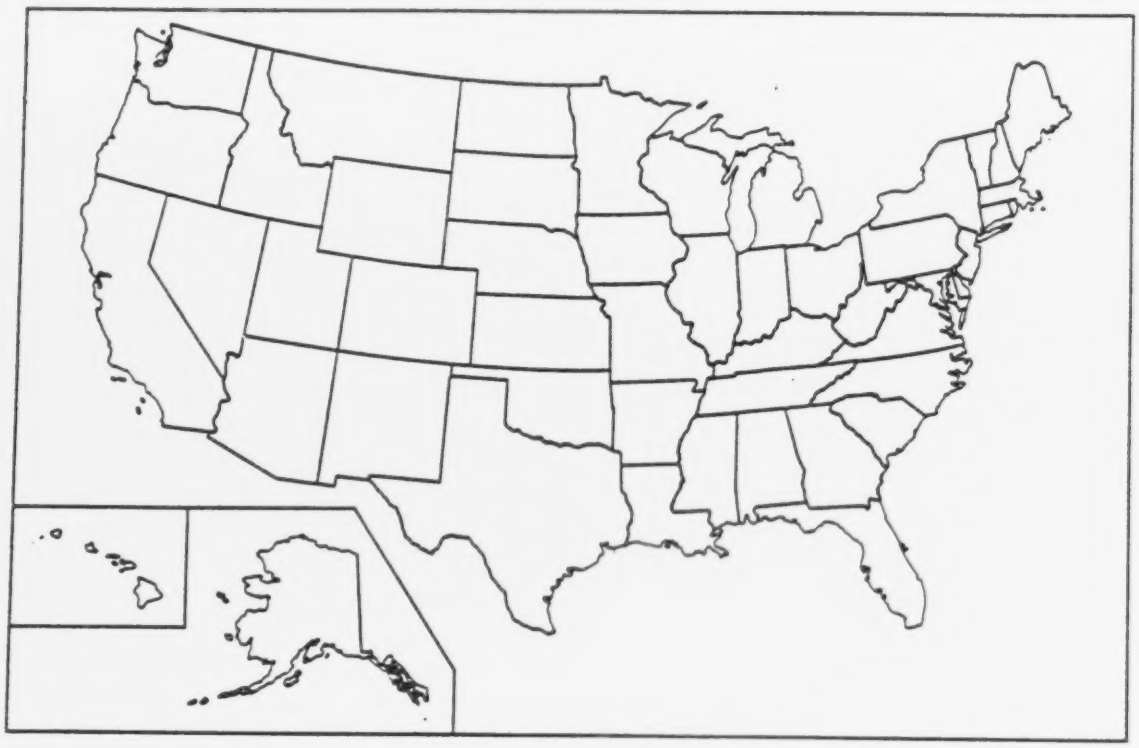
TABLE 4

TORNADO CHARACTERISTICS BY STATE 1953-1980

State	Column A Average Number of Tornadoes/Year	Column B Average Number of Tornado Deaths/Year
Texas	119	11
Oklahoma	53	8
Kansas	43	6
Florida	41	2
Nebraska	35	2
Illinois	27	5
Missouri	27	4
Iowa	27	2
South Dakota	24	0
Indiana	23	8
Mississippi	22	8
Georgia	21	3
Alabama	20	8
Arkansas	20	4
Louisiana	20	3
Colorado	19	0
Wisconsin	18	2
Minnesota	17	3
North Dakota	17	0
Michigan	16	9

FIGURE 3

MAP LOCATION FOR DATA FROM TABLE 4



Answer: Air mass contrast is not as pronounced as in the central United States.

Question 5G: Examine Column B in Table 4 and visually compare by state tornado deaths with number of tornadoes. Do the states with the largest number of tornadoes have the greatest number of deaths?

Answer: Generally not. There is considerable variation in the relationship.

Question 5H: Is the pattern of tornado deaths similar to the data in Tables 1 and 2?

Answer: Yes. It is difficult to explain the number of tornado deaths based just on the number of tornadoes occurring.

Approximately 90 percent of all tornadoes in Illinois follow a path toward the east or northeast(Figure 4). For many years the southwest corner of a basement was recommended as the safest place from a tornado. Some questions regarding tornado safety based on this premise follow along with some possible answers.

Question 6A: Offer several reasons why the southwest corner was considered the safest location in a house threatened by a tornado?

Answer: A below ground location protects you from the strong winds of a tornado and the associated flying debris. In addition, if the house is carried away or tipped over it should move toward the northeast or east away from the southwest part of the basement.

Question 6B: Recent studies have revealed that the southwest portion of a basement may not be as safe as once thought. Why might this be true and what precautions should be taken?

Answer: A house which is not blown off its foundation by a tornado but instead rotated on its foundation could collapse into the basement, including the southwest portion. A position under a sturdy table in the center of the basement may offer greater protection from tornadoes for such circumstances.

Question 6C: What are some of the obvious problems associated with mobile homes located in the path of a tornado?

Answer: Mobile homes do not have basements which are the safest places to be and they can be easily overturned by strong winds.

Question 6D: What precautions should you take if you live in a mobile home which is threatened by a tornado?

FIGURE 4

PATHS OF ILLINOIS TORNADOES 1916-1969

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Answer: Tie-downs should help when winds are strong but you may have to retreat to a storm shelter,if one exists, to have maximum protection when tornadoes are intense.

Question 6E: Assume you are responsible for tornado preparedness in an elementary school. What actions would you take to insure the safety of the students when a tornado warning has been issued?

Answer: You should follow the plan developed for your school and gather in an interior hallway on the lowest floor free from windows. Stay out of wide, free-span areas like auditoriums and gymnasiums. Children should crouch next to the wall while covering their heads with their hands.

Question 6F: What is the difference between a tornado watch and a tornado warning?

Answer: A tornado watch means weather conditions are such that tornadoes are likely to develop in the next few hours. Approximately 70 percent of all tornado fatalities occur within the watch area. A tornado warning is issued by the National Weather Service when a tornado has been observed in the area either visually and/or on a radar screen.

The monthly data in Figure 1 for tornadoes and tornado deaths have been graphed on Figure 5. There are 12 points on the graph corresponding to the 12 months. A trend line, or best fit line, has been visually approximated and placed on the graph so that it reveals the overall relationship between the number of tornadoes and tornado deaths.

Question 7A: What kind of relationship does the trend line reveal? (direct, indirect or undetermined)

Answer: A direct relationship because generally as the number of tornadoes increases so does the number of tornado deaths.

Question 7B: How would you characterize the pattern of points located around the trend line?

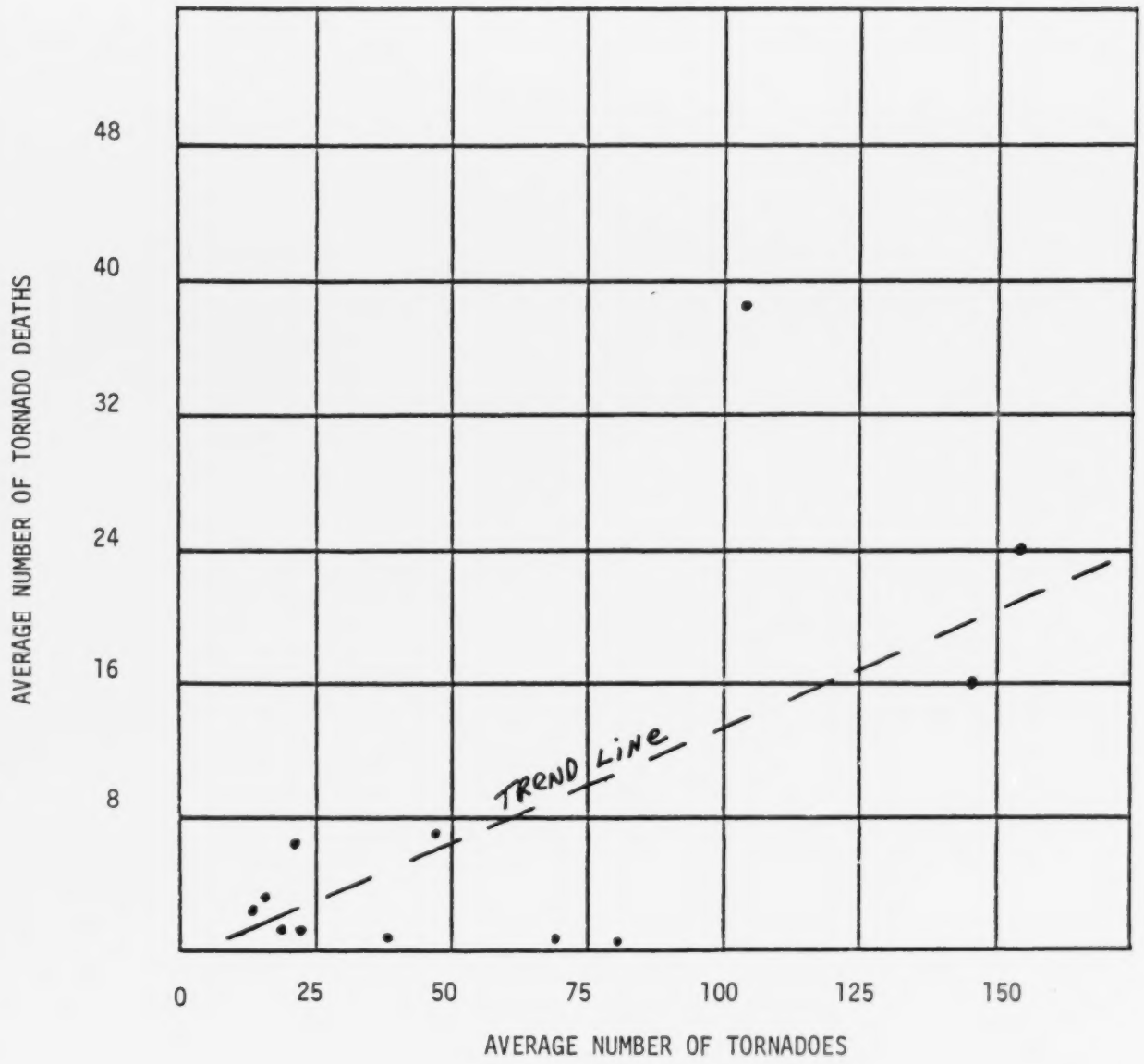
Answer: Overall the points are all fairly close with the exception of one month.

Question 7C: Which month is associated with the point on Figure 5 that is farthest from the trend line?

Answer: The month of May.

FIGURE 5

TORNADO CHARACTERISTICS BY MONTH



This exercise involves transferring the data from Table 4 to Figure 6. The graphing of the 20 points requires that you find the intersection of the average number of tornadoes and average number of tornado deaths for each state. Next, draw a trend line by visually placing the line through the middle of the cluster of points.

Question 8A: Examine the line you drew. How would you characterize the relationship between the two variables?(direct, indirect or undetermined)

Answer: There is a direct relationship.

Now you are going to compare your trend line to one which was obtained mathematically for the same data in Table 4. Many calculators have the capability of finding the equation of a straight line or it can be computed by hand using the technique described by Hammond and McCullagh on pages 253-260 (see references). The equation for the best-fit trend line in Figure 6 is $Y = .07X + 2.25$ where X is the average number of tornadoes by state and Y is the average number of tornado deaths. You will need two sets of X and Y values to draw this line so you can compare it to your trend line. For example, if X equals zero in the previous equation then Y equals 2.25. If X equals 100 then the corresponding Y value is 9.25. Next, use these two sets of X and Y coordinates and mark the two points on Figure 6. Connect the two points with a straight line and write the equation next to the line.

Question 8B: How similar is your trend line to the best fit trend line? Does it reveal a direct relationship?

Answer: Should be very similar and the relationship is direct.

Question 8C: Use the equation for the trend line. If the X value is 50, what is the corresponding Y value?

Answer: The value is 5.75.

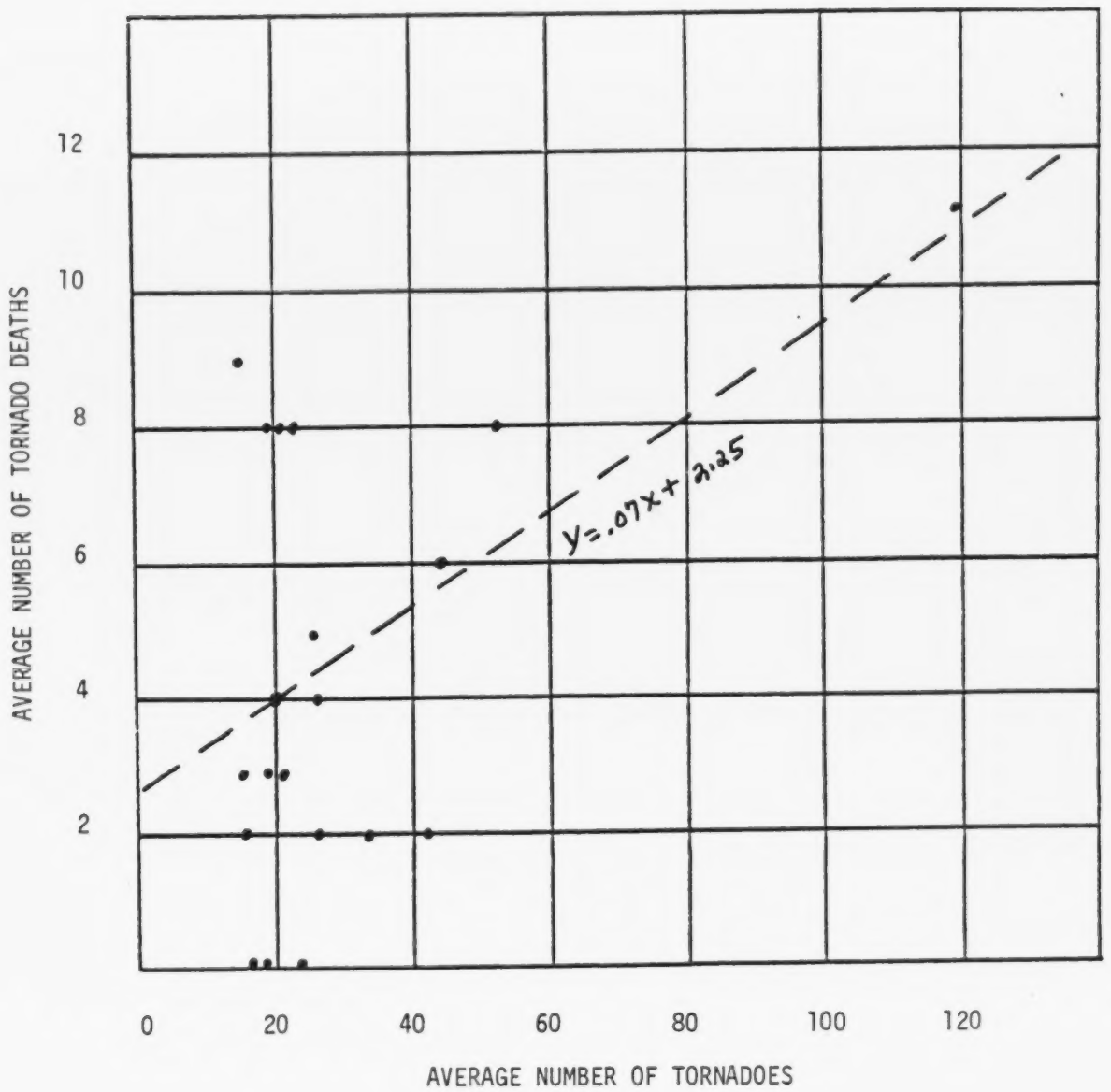
Question 8D: If the Y value for the equation of the trend line is 13, what is the corresponding X value?

Answer: The value is 153.57

Spearman rank correlation coefficients were calculated for the data displayed in Figures 5 and 6 to more accurately determine the strength of the association between the two sets of values on each graph. This technique requires that ranked data be used and has the advantage that since it is a non-parametric statistic it does not have to meet the requirement that the data be normally distributed. It also is less tedious than other methods and yet provides reasonably accurate results. As you complete this exercise be aware that no causal relationship can be inferred from a correlation coefficient alone. Cause and effect can only be confirmed by additional evidence and the judgement of the investigator. For a more detailed discussion of this technique consult

FIGURE 6

TORNADO CHARACTERISTICS BY STATE



Hammond and McCullagh pages 223-228.

The data from Figure 1 which was plotted on Figure 5 has been placed in Table 5 according to rank with the number one being assigned the highest rank. Whenever ties occur the mid-rank method has been used to assign ranks. For details see Arkin and Colton pages 85-87.

Question 9A: Use the information in Table 5 to calculate the Spearman rank correlation coefficient(R_S) where:

$$R_S = 1 - \frac{6 \Sigma D^2}{N^3 - N} \qquad (1)$$

where D^2 = difference in ranks squared

N = number of observations(20 in this case)

Answer: The R_S value is +.38.

Question 9B: The Spearman correlation coefficient is a measure of how well the trend line fits the points on the graph. The R_S value can range from plus one to minus one. The closer R_S is to either extreme the better the overall match. A perfect 1.0 or minus 1.0 means that all the points are on the trend line. Usually a strong direct relationship can be inferred for values greater than .70. A strong indirect relationship can be inferred with values less than minus .70. What does your answer to 9A reveal about the strength of the relationship in Figure 5?

Answer: Since the value of .38 is well below .70 factors other than just tornado frequency must be considered when attempting to understand the variation in tornado deaths.

Question 9C: The data from Table 4, which was graphed in Figure 6, has been ranked in Table 6. Examine the data and then use equation 1 to calculate the Spearman rank correlation coefficient.

Answer: The R_S value is +.24.

Question 9D: What kind of comparison could be made when interpreting the answers to questions 9A and 9C?

Answer: The relationship between tornado frequency and tornado deaths exhibits more variation geographically than seasonally since .24 is less than .38.

TABLE 5

SPEARMAN RANK CORRELATION OF TORNADO DATA 1953-1980

Month	Tornadoes Ranked	Tornado Deaths Ranked	Difference Squared(D^2)
January	12	6.5	30.25
February	10	5	25
March	6	4	4
April	3	1	4
May	1	2	1
June	2	3	1
July	4	12	64
August	5	9.5	20.25
September	7	9.5	6.25
October	8	9.5	2.25
November	9	9.5	.25
December	11	6.5	20.25
			$\Sigma D^2=178.50$

TABLE 6

SPEARMAN RANK CORRELATION OF TORNADO DATA 1953-1980

State	Average Number of Tornadoes/Year Ranked	Average Number of Tornado Deaths/Year Ranked	Difference Squared(D^2)
Texas	1	1	0
Oklahoma	2	4.5	6.25
Kansas	3	7	16
Florida	4	15.5	132.25
Nebraska	5	15.5	110.25
Illinois	7	8	1
Missouri	7	9.5	6.25
Iowa	7	15.5	72.25
South Dakota	9	19	100
Indiana	10	4.5	30.25
Mississippi	11	4.5	42.25
Georgia	12	12	0
Alabama	14	4.5	90.25
Arkansas	14	9.5	20.25
Louisiana	14	12	4
Colorado	16	19	9
Wisconsin	17	15.5	2.25
Minnesota	18.5	12	42.25
North Dakota	18.5	19	.25
Michigan	20	2	324
			$\Sigma D^2=1009$

Table 7 contains Spearman rank correlations for a slightly different time period than the previous tables.

Question 10A: What do the three rank correlations reveal about the nature, as well as the strength of the relationships?

Answer: Each is a direct relationship with the rank correlation of .66 for tornado damages and deaths being the only one which exhibits a noteworthy value.

Question 10B: Why do you suppose that the number of tornado deaths has a stronger association(.66) with tornado damages than with the number of tornadoes(.14)?

Answer: Not all tornadoes cause damage and those that do destroy structures likely shelter people who could become victims of high winds, flying debris and collapsing walls.

TABLE 7

SPEARMAN RANK CORRELATIONS 1953-1978

Variables Compared for 20 States	Rank Correlation(R_s)
Average Number of Tornadoes/Year vs Average Number of Tornado Deaths/Year	+.14
Average Number of Tornadoes/Year vs Average Tornado Damages/Year	+.22
Average Tornado Damages/Year vs Average Number of Tornado Deaths/Year	+.66

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